Plant Cell Walls - a multilayered structure unique to plants

Functions of cell walls:

- Provide tensile strength and limited plasticity which are important for
  - keeping cells from rupturing from turgor pressure
  - turgor pressure provides support for non-woody tissues
- Thick walled cells provide mechanical support
- Tubes for long-distance transport
- Cutinized walls prevent water loss
- Provide mechanical protection from insects & pathogens
- Physiological & biochemical activities in the wall contribute to cell-cell communication

During growth and development

- Cell division involves synthesis of new cell wall
- Cell enlargement involves changes in cell wall composition
- Cell differentiation involves changes in cell wall composition

Cell walls consist of 3 types of layers

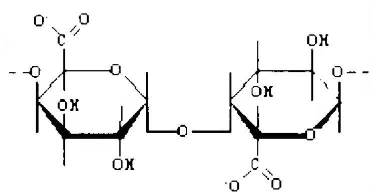
Middle lamella: This is the first layer formed during cell division. It makes up the outer wall of the cell and is shared by adjacent cells. It is composed of pectic compounds and protein.

Primary wall: This is formed after the middle lamella and consists of a rigid skeleton of cellulose microfibrils embedded in a gel-like matrix composed of pectic compounds, hemicellulose, and glycoproteins.

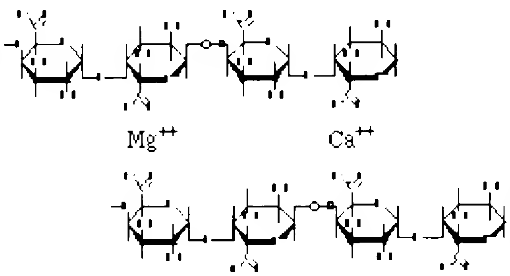
Secondary wall: formed after cell enlargement is completed. The secondary wall is extremely rigid and provides compression strength. It is made of cellulose, hemicellulose and lignin. The secondary wall is often layered.

Composition of cell wall

Pectic acid
- polymer of around 100 galacturonic acid molecules

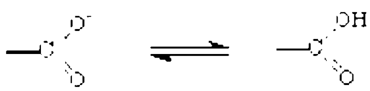


galacturonic acid



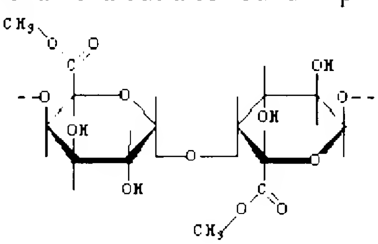
Pectic acid with salt bridges

Because the carboxyl groups on the galacturonic acid molecules are weak acids, they can exist in negatively charged and uncharged states depending on protonation (see fig below). The extent to which the molecules are protonated is pH dependant and related to the pKa (the pH at which the two forms are in equilibrium).



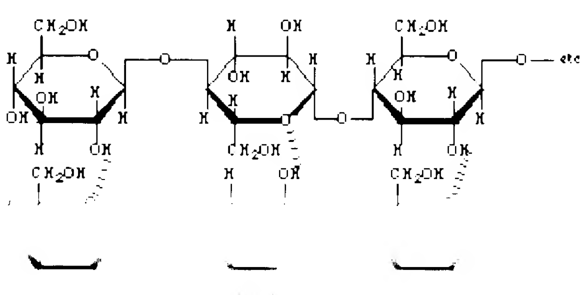
Pectin

- polymer of around 200 galacturonic acid molecules
- many of the carboxyl groups are methylated (COOCH3)
- less hydrated then pectic acid but soluble in hot water
- another major component of middle lamella but also found in primary walls

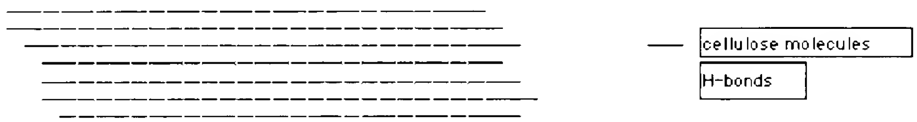


Cellulose: polymer of glucose - typically consisting of 1,000 to 10,000 beta-D-glucose residues - major component of primary and secondary wall layers.

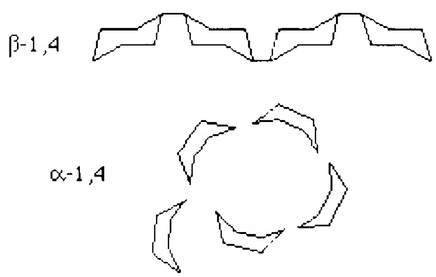
Cellulose polymers associate through H-bonds. The H-bonding of many cellulose molecules to each other results in the formation of **micro fibers** and the micro fibers can interact to form **fibers**. Certain cells, like those in cotton ovules, can grow cellulose fibers of enormous lengths.



Cellulose fibers usually consist of over 500,000 cellulose molecules. If a fiber consists of 500,000 cellulose molecules with 5,000 glucose resides/cellulose molecule, the fiber would contain about 2.5 billion H-bonds. Even if an H-bond is about 1/10 the strength of a covalent bond, the cumulative bonding energy of 2.5 billion of them is awesome. It is the H-bonding that is the basis of the high tensile strength of cellulose.

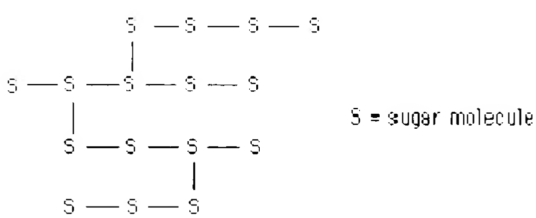


Starch is also a polymer of glucose. However, instead of a beta-1,4 linkage between glucose molecules, starch uses an alpha-1,4 linkage. The difference is due to the conformation of the ring structure. The alpha-1,4 linkage causes the polymer to take on a twisted configuration instead of the linear shape of cellulose. Thus, starch forms globular structures. Starch molecules are often branched, which also prevents linear arrays from forming. In plants, starch is only found in plastids (not in walls or cytoplasm).



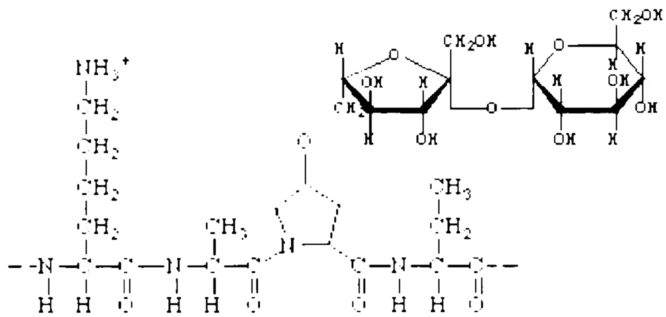
Hemicellulose is a polysaccharide composed of a variety of sugars including xylose, arabinose, mannose. Hemicellulose that is primarily xylose or arabinose are referred to as xyloglucans or arabinoglucans, respectively.

Hemicellulose molecules are often branched. Like the pectic compounds, hemicellulose molecules are very hydrophilic. They become highly hydrated and form gels. Hemicellulose is abundant in primary walls but is also found in secondary walls.



[illegible] wall proteins are characterized [illegible] having an abundance of the amino [illegible]

hydroxyproline. Strucural proteins are found in all layers of the plant cell wall but they are more abundant in the primary wall layer



Like the cell wall carbohydrates, glycoproteins are hydrophilic and can form H-bonds and salt bridges with cell wall polysaccharides

In addition to hydroxyproline, cell wall proteins are often high in the amino acids proline and lysine. The NH3+ on lysine provides positive charges along the peptide backbone. The positive charges residues can associate with negatively charged groups on pectic acids, etc. In addition to electrostatic interactions, H-bonds also form between amino acid side chains and cell wall carbohydrates.

Another type of structural cell wall protein, called **extensin**, can form covalent bonds with other **extensin** proteins through the amino acid tyrosine In **extensin**, the tyrosines are evenly spaced and when they bond with tyrosine on another **extensin** molecule, the can wrap around other cell wall constituents "knitting" the wall together

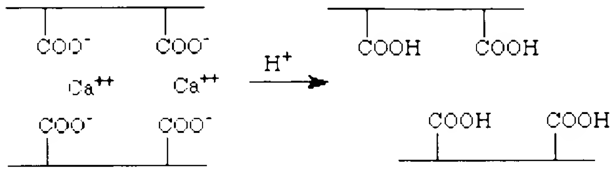
The amount of **extensin** changes with development Cells that have thick, hard walls are often rich in **extensin** (i.e., sclerids and fibers) the amount of **extensin** produced is dependent on mechanical wounding, infection and these responses are mediated by plant hormones.

Cell walls also contain functional proteins Enzymatic activities in cell walls include:

- Oxidative enzymes - peroxidases
- Hydrolytic enzymes - pectinases, cellulases
- "Expansins" - enzymes that catalyze cell wall "creep" activity

General functions of cell wall enzymes include protection against pathogens, cell expansion, cell wall maturation.

1) Wall acidification - H+ATPase in plasma membrane 'pumps" H+ from cytoplasm into cell wall. The pH of the wall drops and carboxylic acids become protonated and 'salt bridges" are broken.



In addition, the enzyme "expansin" is activated and causes cellulose micro fibers to slip (mechanism of expansin action is unknown). This results in cell wall "creep".

Hydrolytic enzymes like cellulase and pectinase, "degrade" cell walls by breaking polymers into smaller subunits or by breaking crosslinks.

Back to Lecture Topics

Back to course info page

Click here to go back to lab page menu